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STUDIES ON THE LIFE HISTORY AND HABITS OF THE JOINTWORM FLIES OF THE GENUS HARMOLITA (ISOSOMA), WITH RECOMMENDATIONS FOR CONTROL.[1]

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INTRODUCTION.

Owing to the chaotic condition existing until recently in the classification of the genus Harmolita (Isosoma), it has been practically impossible to obtain specific determinations, and this fact has largely prevented economic workers from undertaking detailed life-history studies of the various species. Some members of this genus are of great economic importance, the losses directly traceable to them

[1] The writer wishes to acknowledge his indebtedness to various members of the branch of Cereal and Forage Insect Investigations who furnished material from time to time for breeding work, but more particularly to Messrs. W. T. Emery, Philip Luginbill, and T. H. Parks, and to Dr. Henry Fox, who have been associated with him and have rendered valuable assistance in breeding, and to Mr. A. B. Gahan for kindly criticisms of the manuscripts.

running into the millions of dollars every year. Despite this fact very little has been known concerning the identity and habits of the species which cause these losses. For example, it was not known definitely whether *Harmolita tritici* Fitch, the most important member of the genus, had a dozen host plants or whether it was confined to wheat alone. The object of this paper, therefore, is to place on record in as brief a manner as possible the main facts, in so far as they have been developed, in the life histories of the species that have been studied thus far, and to propose a basis for control.

The species infesting the grain crops will be considered first, then those affecting the cultivated grasses, and lastly the species living in wild grasses. Nearly every species is of either direct or indirect economic importance. Those affecting the grain crops and the cultivated grasses are obviously of direct economic importance because of the very considerable losses entailed by their depredations or their potential capacity for injury. The importance of the different species varies greatly since the damage inflicted by some is far greater than that caused by others. The economic aspect of those species affecting wild grasses is less obvious. They do not cause a loss to the farmer, but on the contrary probably are an advantage to him, since they serve as intermediate hosts for the many parasitic insects which play such an important rôle in the natural control of the species infesting cultivated crops. Without these intermediate hosts it is doubtful whether some of the parasites would be able to maintain themselves under the abnormal conditions created by cultivation. The more important species of parasites are common to the majority of species of Harmolita, however, and consequently are able to survive those periods during which there is a lack of hosts breeding in cultivated crops, by turning their attention to related species breeding in wild grasses.

It is difficult to estimate the value of jointworm parasites in terms of dollars and cents to the wheat-growing regions east of the Mississippi River. The writer is convinced, however, that farmers would have been obliged to resort to artificial measures of control for the wheat jointworm years ago had it not been for the efficiency of these parasites. The parasites of the jointworms will be treated in a paper to be published subsequently.

SPECIES INFESTING THE GRAIN CROPS.

THE WHEAT JOINTWORM.[1]

Harmolita tritici probably is the most important species in the whole genus, since it causes very serious losses in nearly all the wheat-producing States east of the Mississippi River and in a large part of

[1] *Harmolita tritici* Fitch.

Missouri. It has been known as a serious wheat pest since 1848 and it is strange that it has not extended its range into the great wheat-producing States of Texas, Oklahoma, Kansas, Nebraska, the Dakotas, and farther west. At present no satisfactory explanation of this fact can be offered, although the species undoubtedly will invade that part of the country sooner or later. *Harmolita tritici* has been confused in literature with *H. hordei*, *H. secalis*, *H. captiva*, *H. vaginicola*, *H. elymicola*, and doubtless with others. It was first described by Asa Fitch (3)[1] in 1859 as *Eurytoma tritici* and was subsequently described under several names by various authors. Entomologists disagreed for years regarding this species before the phytophagous habits were definitely established.

MANNER OF INJURY.

A plant infested by the wheat jointworm may not show any external signs of infestation whatever, or the stems may be distorted and have wartlike elevations on them (Pl. II, C). In any case the stem at the point infested is hard and woody and where there is no distortion the point of infestation may be readily detected by pinching the stem between the thumb and forefinger. These infested places usually occur above the second or third joint from the root but may occur above any joint. In badly infested fields several joints may be affected and a large number of plants may fall (Pl. I, B), thus greatly reducing the yield. It is not necessary, however, that the plants fall or lodge to reduce the yield greatly. The writer has taken heads from healthy and from infested stems, carefully measured them against one another, and has found that the grain of the infested plants from the same number of heads of exactly the same length as the uninfested were very much lighter and of much smaller volume (Pl. I, A).

When plants lodge or fall to a considerable extent the yield is far more reduced than when the plants remain standing. In the first place, the plants that fall, in nearly every case, will escape the binder. Should the binder reach them they will be bound so near the butt of the bundle that most of them will fall out with subsequent handling. Could they be bound securely the yield would scarcely be 50 per cent as large as that from heads of equal length taken from normal plants. The grains, moreover, are small and somewhat shriveled. The inferior grain seems to be due to improper nourishment during the growing period. The young larvæ develop in the walls of the stem and disarrange the fibro-vascular bundles, thus greatly weakening the stem at this point. A storm, light rain, or heavy wind will cause the plant to bend over at the point of in-

[1] Numbers in parentheses refer to "Literature cited," p. 26.

festation, as the plants are thus made much more top-heavy. As the growing larvæ consume proportionately large amounts of sap, the developing wheat kernels are constantly robbed of their nourishment and suffer accordingly.

A field of wheat badly straw-fallen usually is attributed to the depredations of the Hessian fly by the average farmer, and very often the fly is wrongly credited year after year, in the States east of the Mississippi River, with serious and widespread injury that is chargeable to the jointworm.

HOST PLANTS.

During repeated trials covering a number of years this species was never induced to breed in any plant but wheat. It never has even

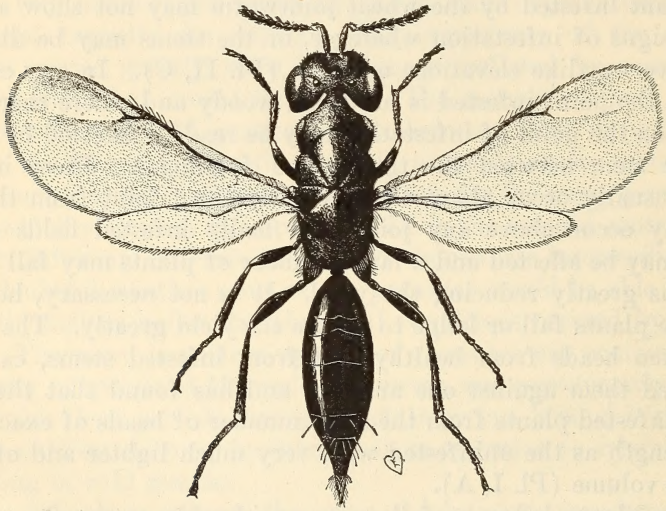
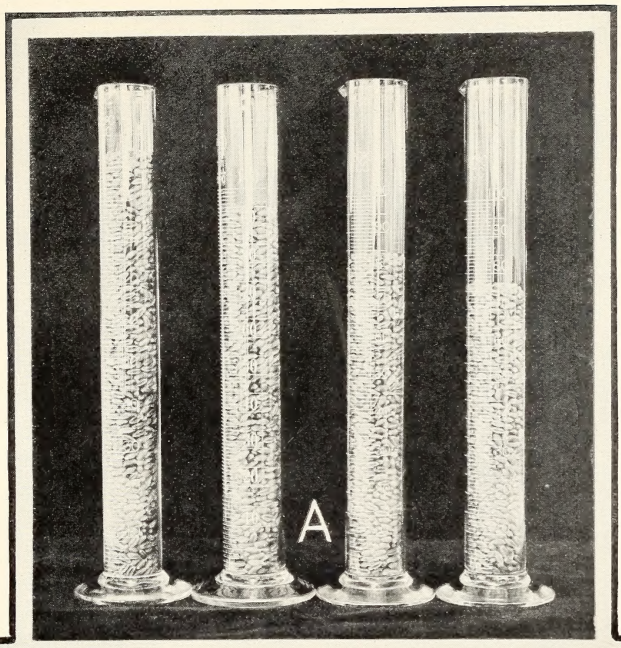


FIG. 1.—The wheat jointworm (*Harmolita tritici*): Adult female. Greatly enlarged. (The head is tilted back somewhat so as to show the groove in front.) (Author's illustration.)

been observed to attempt oviposition in any other plant. The stems of barley and rye particularly do not differ greatly from wheat, but they seem to be distasteful to *tritici*.

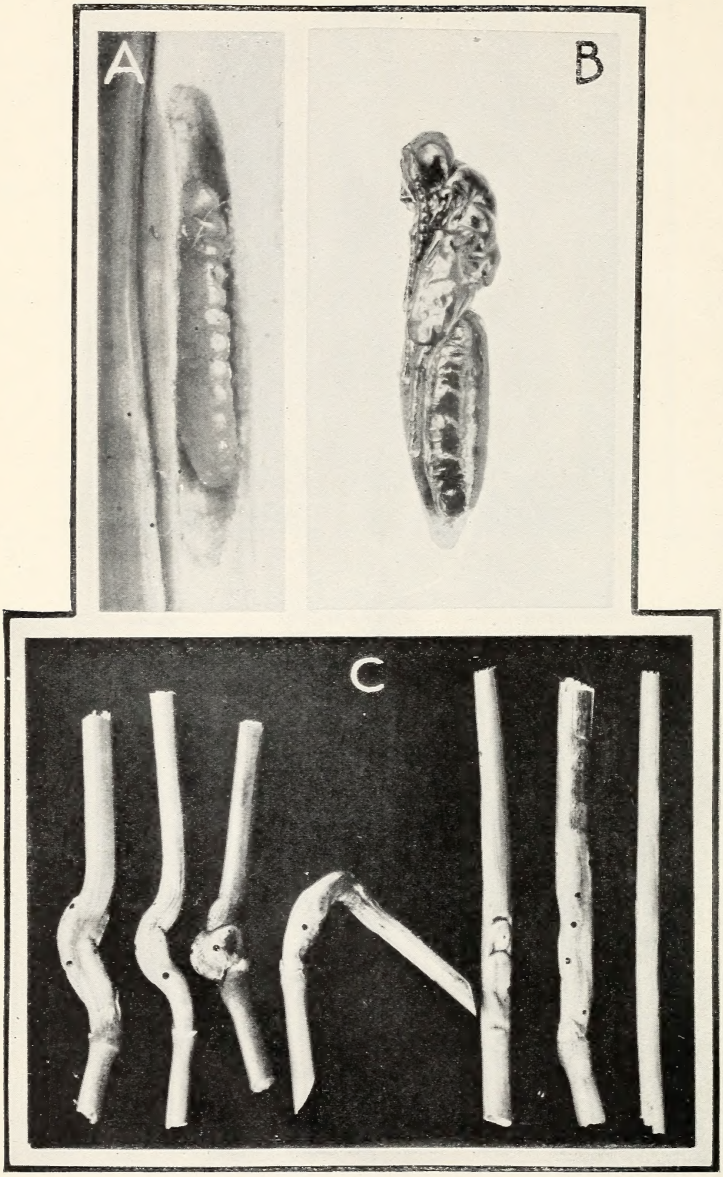
LIFE HISTORY.

There is only one generation a year. The adults (fig. 1) emerge in May and deposit their eggs in the stems of growing wheat just about the time the heads begin to appear. The life of adults lasts from a few days to a week or more, depending upon the temperature. The eggs (fig. 2, *a*, *b*) hatch in about 10 days. The larvæ mature in



JOINTWORM FLIES OF THE GENUS HARMOLITA.

A, Comparative yields from healthy wheat plants and those infested with the jointworm (*Harmolita tritici*); reading from left to right, the yield from 85 uninfested stems, 85 stems with one node infested, 85 stems with two nodes infested, and 85 infested fallen straws. The heads were all measured against each other, so that, for example, any head from the lot of uninfested plants had a corresponding head of equal length in all the infested lots; B, Field badly infested with the jointworm. Note the large percentage of fallen straws.



JOINTWORM FLIES OF THE GENUS HARMOLITA.

H. tritici: A, Cell with the top lifted off exposing the larva (greatly enlarged); B, pupa (greatly enlarged); C, characteristic galls (about natural size).

about three weeks or a month from date of oviposition. They molt at least three times and possibly four. The larvæ (Pl. II, A) are yellow, footless grubs, three-sixteenths of an inch long at maturity. They remain in the larval stage until late fall or early winter, when the majority usually change to pupæ (Pl. II, B), the remainder pupating very early in the spring.

Males normally occur, although in confinement this species will breed parthenogenetically, in which case the progeny are all males.

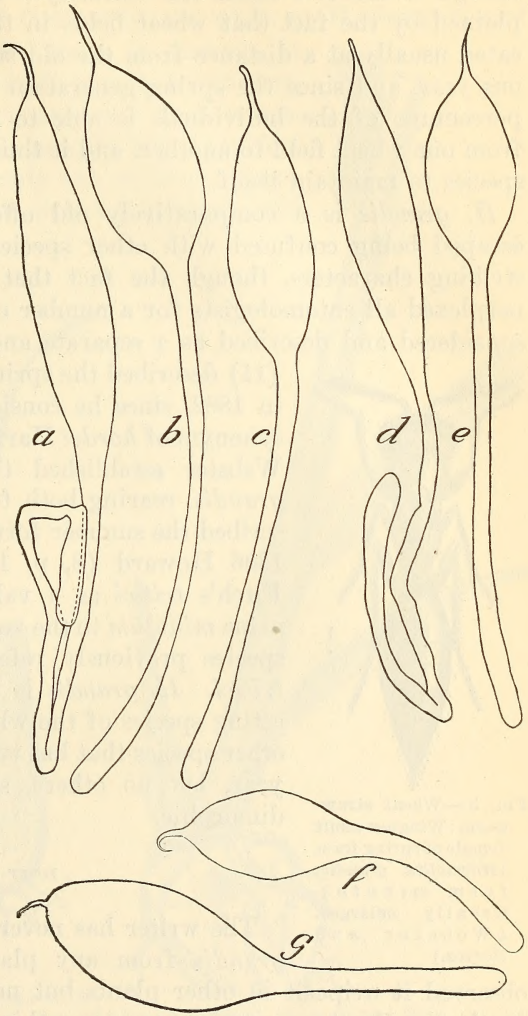


FIG. 2.—Eggs of species of Harmolita: *a*, *H. tritici*, after oviposition; *b*, *H. tritici*, before oviposition; *c*, *H. elymivora*, before oviposition; *d*, *H. hordei*, after oviposition; *e*, *H. hordei*, before oviposition; *f*, *H. grandis*, form *minuta*; *g*, *H. agropyrophila*. All greatly enlarged. (Original.)

THE WHEAT STRAW-WORM.[1]

Harmolita grandis ranks next to the wheat jointworm in importance as an enemy of wheat. Were it not for the ease with which it can be controlled it probably would be more destructive, and might even command greater prominence than the Hessian fly, due to the fact that there are two generations a year. At any rate, it is at present the most important of the jointworm group west of the Mississippi River, where it often causes widespread injury. *H. grandis* is probably the most widely distributed species in the United States, occurring usually in greater or less numbers wherever wheat is grown. Though occurring in

[1] *Harmolita grandis* Riley.

practically every wheat-growing section east of the Mississippi River, it rarely has caused any serious losses in recent years, although it exacts a small toll annually. This possibly may be explained by the fact that wheat fields in the Eastern States are located usually at a distance from the old stubble fields of the previous year, and since the spring generation is wingless, only a small percentage of the individuals is able to make the journey safely from one wheat field to another, and it thus becomes difficult for the species to maintain itself.

H. grandis is a comparatively old offender, but probably has escaped being confused with other species, as it has some rather striking characters, though the fact that it is dimorphic greatly perplexed all entomologists for a number of years. Each form was considered and described as a separate and distinct species. Riley (11) described the spring form as *Isosoma tritici* in 1882, since he considered Fitch's *tritici* as a synonym of *hordei* Harris. In 1884 the late F. M. Webster established the dimorphic habits of *grandis*, rearing both forms, and Riley (12) described the summer form as *Isosoma grande*. In 1896 Howard (8, p. 10) definitely established Fitch's *tritici* as a valid species and gave the name *minutum* to the vernal generation of Riley's species previously referred to in literature as *tritici*. *H. grandis* is probably the most interesting species of the whole group. There is one other species that has two generations during the year, but no others, so far as is known, are dimorphic.

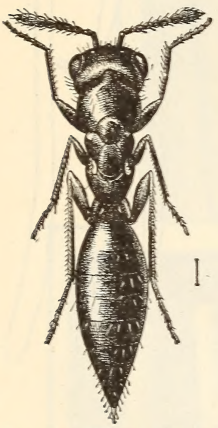


FIG. 3.—Wheat strawworm: Wingless adult female of spring form (*Harmolita grandis*, form *minuta*). Greatly enlarged. (Webster and Reeves.)

HOST PLANTS.

The writer has never succeeded in rearing *H. grandis* from any plant but wheat. He has observed it oviposit in other plants but no larvæ were ever found in them. Further experiments along this line may disclose other hosts. As it is found in sections where very little wheat is grown consecutively, it seems as though there must be at least one other host.

LIFE HISTORY AND MANNER OF INJURY.

The spring form (fig. 3) (*H. grandis*, form *minuta*) attacks the wheat plants when they are small (fig. 4), the eggs (fig. 2, *f*) being deposited in the base of the young plant. The developing larva totally destroys the tiller affected, and if the plant has not tillered

it kills the entire plant. The larva develops within and right at the base of the plant, usually making the plant somewhat bulblike at this point (fig. 5). This generation emerges during March and April in the Eastern and Central States, while in Washington and probably in other Pacific States it emerges in April. This spring generation usually is wingless, though occasionally specimens may have wings. These winged individuals usually are imperfect in that they often have only two or three wings. Sometimes only the front pair are present, and again only the hind wings. Males occasionally occur in this generation, though rarely.

FIG. 4.—Wheat straw-worm: Stage of development of wheat plant at time of oviposition of spring form (*Harmolita grandis*, form *minuta*). Enlarged illustration at right shows the point where egg is deposited. (Webster and Reeves.)

FIG. 5.—Wheat straw-worm: Pupa of summer form (*Harmolita grandis*, form *grandis*) as it normally occurs in the field. The tiller thus attacked is always killed. (Webster and Reeves.)

The summer form (fig. 6) (*H. grandis*, form *grandis*) emerges in May and deposits eggs (fig. 7, *d*, *e*) in the growing wheat plants slightly above the joints, often placing the eggs directly in the cavity of the stem, where they hatch in about 5 days. Sometimes

they are placed in the walls. Several eggs are placed occasionally in the same joint but the writer never has found more than one full-grown larva at a joint, the others apparently being killed by the surviving larva. The larva rasps the inner walls of the stem, sucks the juices, and subsequently forms a neat little cell within the joint (Pl. IV, B). In all the winter wheat areas the effect upon the plant is to cut down the yield of grain, while in places where both spring and winter wheat are sown, often in adjoining fields, the summer form turns its attention to the spring wheat in preference to the older and tougher plants of the winter wheat. Spring wheat is affected very much in the same manner as winter wheat is

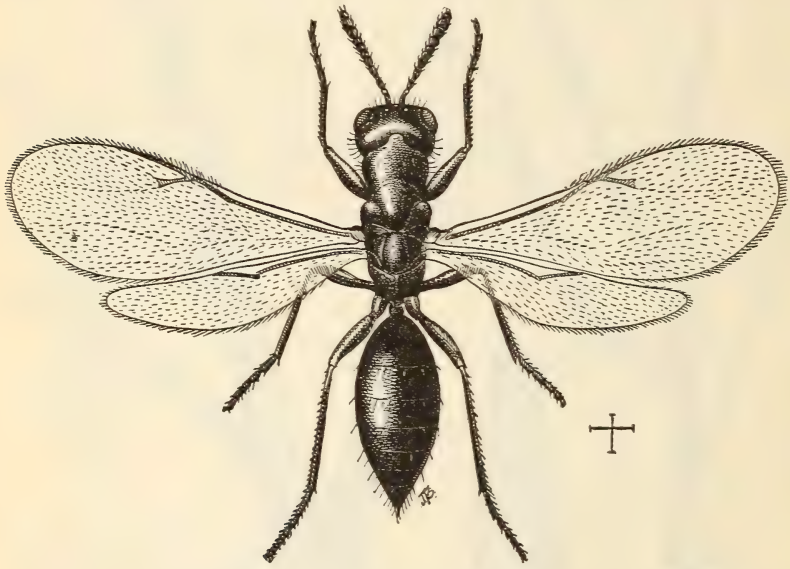


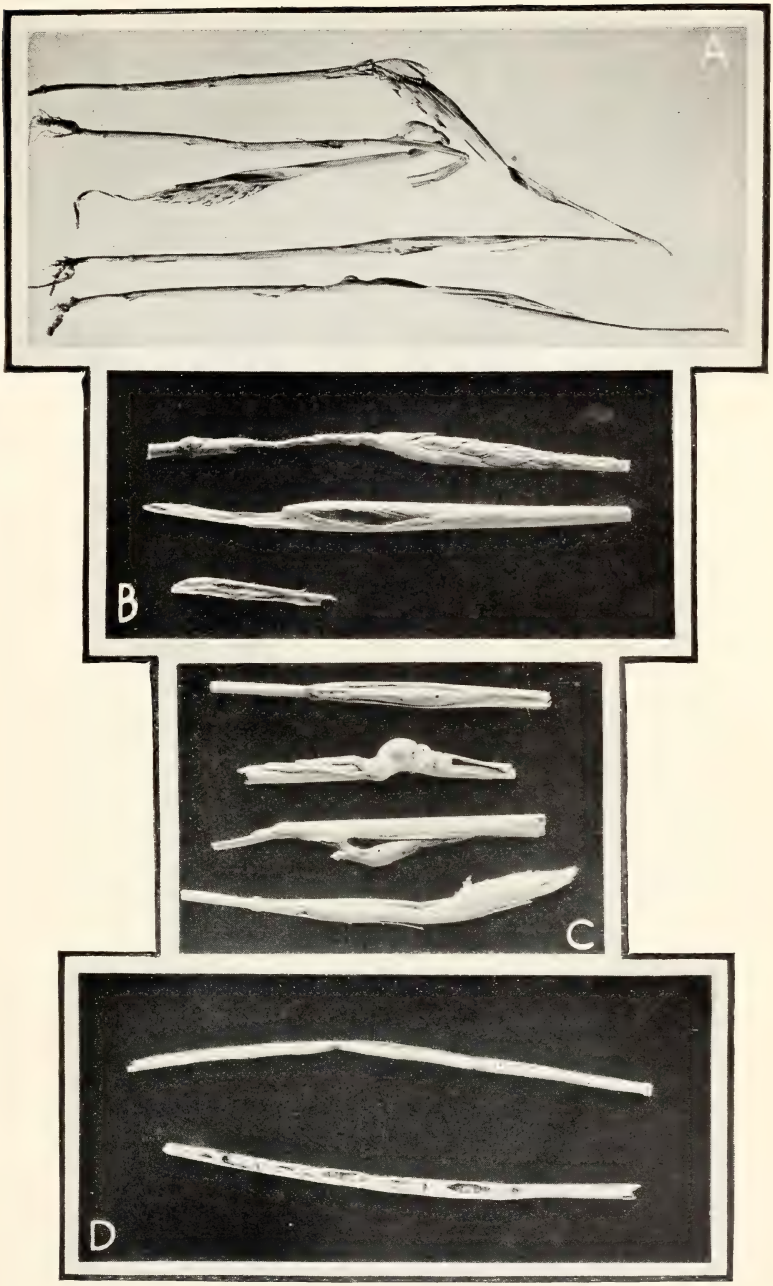
FIG. 6.—Wheat straw-worm: Adult female of summer form (*Harmolita grandis*, form *grandis*.) Greatly enlarged. (Webster and Reeves.)

injured by the first generation (form *minuta*). The summer generation remains in the old wheat stubble, pupating in the fall. The spring generation, as previously stated, emerges in March and April. The writer has never seen males of the summer generation.

THE WHEAT SHEATH-GALL JOINTWORM.[1]

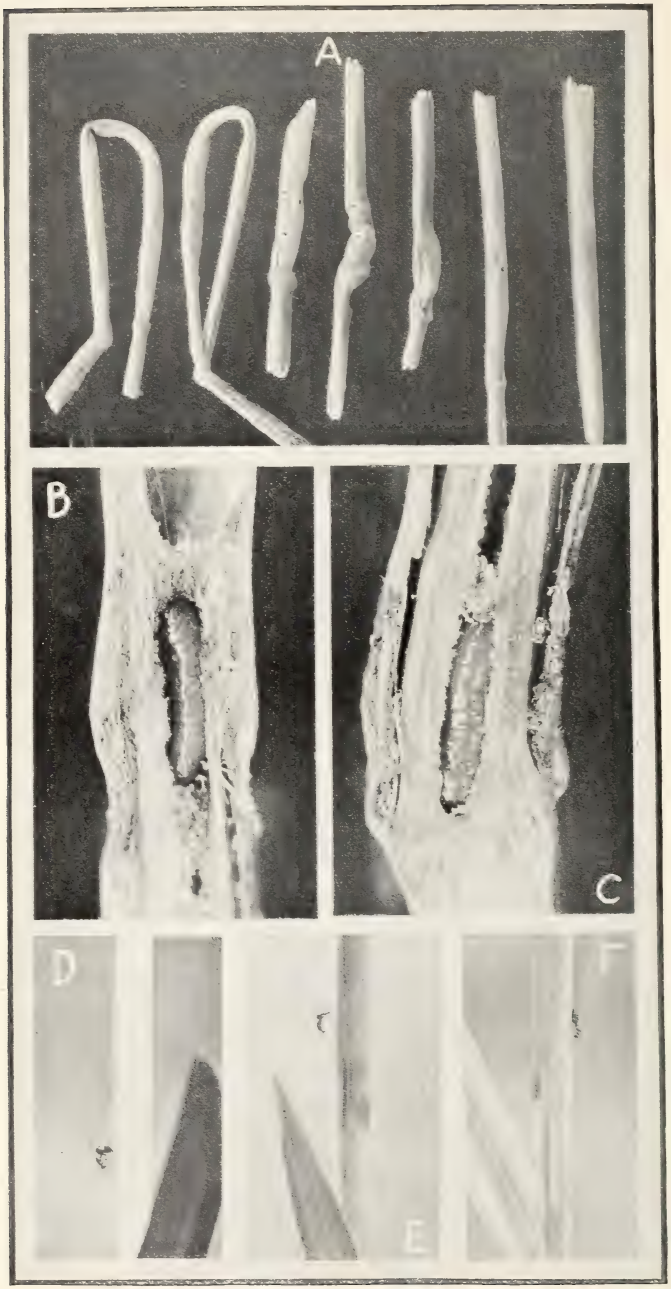
Harmolita vaginicola was not described until 1916 (2), though the typical form of its injury to wheat was recorded in literature many years ago. There are specimens in the National Museum collection that bear the manuscript name *Pteromalus hordei* Harris, which were collected in Virginia in the early fifties, and some that

[1] *H. vaginicola* Doane.



JOINTWORM FLIES OF THE GENUS HARMOLITA.

A, Characteristic manner in which *H. vaginicola* dwarfs wheat plants. These plants rarely form grain. About one-third natural size; B, Head from a plant dwarfed by *H. vaginicola* with the surrounding leaf sheath removed, showing the galls in the sheath and not in the stem. Slightly reduced; C, Characteristic galls of *H. vaginicola*. Note the rootlike growth at the base of galls. Slightly reduced; D, Galls of *H. captiva* in bluegrass (*Poa pratensis*). There is little external evidence of the galls. Note that the galls are placed end to end. Slightly reduced.



JOINTWORM FLIES OF THE GENUS HARMOLITA.

A, Characteristic galls of *H. hordei*, some clearly showing that the plants were straw-fallen. About actual size; B, Larva of *H. grandis* form *minuta* in a cell in the center of a wheat stem. Greatly enlarged; C, Larva of *H. albomaculata* in a timothy stem (*Phleum pratense*). Greatly enlarged; D, *H. hordei* touching the ovipositor to barley stem, the first process in oviposition; E, forcing the ovipositor into the stem, the second step; F, the ovipositor completely down, the third and last step, and the abdomen resting lightly against the stem. About natural size.

were collected in Ontario, Canada. There are specimens in the Harris collection of the Boston Society of Natural History bearing the label *Isosoma tritici* that were collected in Virginia in 1852. There are also specimens of *tritici* in the same lot. As late as 1892 F. M. Webster (13) stated that—

> He had not reared the depredator, and though in many respects the attack seemed to agree with that of *Isosoma hordei*, as described by Harris and Fitch, yet in many other features it appeared different. In all cases—and he had examined hundreds of wheat straws from northern Ohio—the attack was always above the upper joint. In two cases the upper joint and the one below had been attacked. From many thorough examinations he had found that the stem itself had not been eaten into, the cells being formed in the sheath, but owing to the pressure of the galls on the tender stem the latter had become distorted and the upper portion with the head, where one was produced, was greatly aborted.

This so accurately describes the injury that no doubt is left as to the identity of the insect in question or as to the fact that the species was very widespread and may have been a more serious pest in the early days in Michigan and northern Ohio than *H. tritici*. This is one of the reasons why entomologists had such controversies over *tritici* in the early days. There is not the slightest doubt in the

FIG. 7.—Eggs of species of Harmolita: *a*, *H. hesperus*; *b*, *H. websteri*; *c*, *H. albomaculata*; *d*, *H. grandis*, form *grandis*, after oviposition; *e*, *H. grandis*, form *grandis*, just before hatching. All greatly enlarged. (Original.)

writer's mind that if the types of all of the early described species now referred to synonymy were in existence to-day and were recognizable, *vaginicola* would be found among them. *H. vaginicola* was very probably confused with *hordei* and *secalis* as well as *tritici*.

The writer's earliest personal records of *vaginicola* are from collections from eastern Ohio in 1912. Since then he has recorded it from Michigan, New York, and Pennsylvania and has been rearing it in confinement since 1914. Mr. Desla Bennion sent the writer specimens from Salt Lake as early as 1914 and Mr. L. P. Rockwood recently submitted a single gall from Oregon, from which this species has emerged.

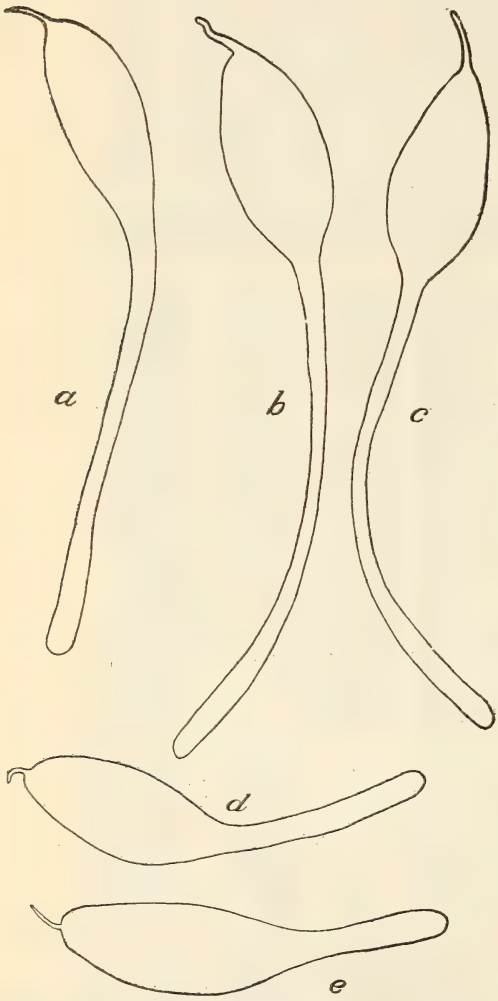


FIG. 8.—Eggs of species of Harmolita: *a*, *H. vaginicola*; *b*, *H. secalis*; *c*, *H. elymicola*; *d*, *H. maculata*; *e*, *H. poae*. All greatly enlarged. (Original.)

MANNER OF INJURY.

H. vaginicola affects the plants in a very peculiar way, and only one other species, namely, *atlantica*, a gall-former in *Agropyron* sp., is known to the writer to affect a plant in a similar manner. The eggs (fig. 8, *a*) are deposited in the tender leaf sheath surrounding the embryonic head. It does not seem possible that the insect can always locate this delicate structure so easily. The result is that as the plant grows, the leaf sheath surrounding the developing head becomes fleshy and thick instead of remaining thin and leaflike. Later this thickened, fleshy leaf becomes hard and woody and compresses the stem to such an extent that little or no sap can reach the developing head. Consequently the head usually protrudes only an inch or

two beyond the leaf sheath. Sometimes it does not even burst through the sheath and rarely if ever do any of these heads contain grain (Pl. III, *A*, *B*, *C*). The larval cells are contained in the hardened leaf sheath.

Why this species has not become the dominant pest of wheat, at least among the jointworm group, is inexplicable. It is prolific and the plants attacked seldom if ever produce any grain. The species has been in this country for at least 55 or 60 years. The only explanation that occurs to the writer, of the reason it has not proved more injurious, is that it seems unable to breed in strong, well-grown plants. In other words, by the time the adult emerges in the spring, the majority of the wheat plants are well grown and about to begin heading. This is true, at least, for the States east of the Mississippi River. It seems necessary that plants be small and the heads in an immature tender stage for this species to be able to breed in them. The species absolutely refuses to oviposit in large plants that are about ready to head. Should this pest once become established in the spring wheat belt, the writer is of the opinion that it will be a very serious pest, owing to the fact that the adults would undoubtedly emerge when the wheat plants were young and tender and most attractive to them, as is known to be the case with *grandis* where the spring and winter wheat regions overlap.

HOST PLANTS.

H. vaginicola steadily has refused to breed in any plant other than wheat. The writer never has observed it even to attempt oviposition in any other plant, and, as previously stated, the plants must be young and tender or it will refuse them.

LIFE HISTORY.

There is only one generation a year. The larvæ remain in the wheat stubble until the following spring, then pupate and emerge as adults in May. The abdomen of the female contains 60 to 70 eggs. They are normally thelyotokous. During the 4 years the writer has been rearing this species in confinement no males have been observed, though thousands of specimens have been reared.

THE BARLEY JOINTWORM.[1]

The records show *Harmolita hordei* to be the oldest species recorded in literature in the United States, and, like *tritici*, it has caused a storm of argument. In fact, for many years it was sup-

[1] *Harmolita hordei* Harris.

posed to be the only species present, and even *tritici* was considered a varietal form of it. Harris (7) described this species in 1830. Along in the twenties it caused such serious injury to barley in Massachusetts that the growing of this crop was abandoned in some sections. For years it was a scourge to barley-growing sections in the East. The Eastern States have largely ceased growing barley for a number of years now, and consequently have suffered very little injury. The barley-growing section has moved west, Wisconsin, Minnesota, and the Dakotas now being the most important barley States. Fortunately *hordei* does not seem to have been introduced artificially into those sections, which is the only plausible way it could be transferred from the main barley section in the East. Barley, unlike wheat, is not grown generally in the intervening States, so that there is no chance for *hordei* to spread gradually westward as *tritici* seems to have done.

During the late summers of 1913 and 1914 the writer visited portions of New York State that were formerly great barley-growing centers. Only a very few infested barley stubbles were found after extended search in 1913, and none were found in 1914. Very little barley is grown there now. The fields, as a rule, are widely separated and the stubble usually is plowed under before *hordei* has had an opportunity to emerge, consequently it has been almost exterminated. This is one of the very rare instances of a once serious pest becoming practically extinct. Its scarcity is such that the writer had never seen a specimen of *hordei* until the spring of 1914, except the few fragmentary specimens in museums.

H. hordei has been confused with *tritici* and *secalis* undoubtedly, and probably with *vaginicola* and others. As the coloration of the legs of *hordei* varies to a considerable degree it is not surprising that confusion arose years ago, since that was one of the main characters used in identifying the species.

MANNER OF INJURY.

Barley plants are affected by *hordei* (Pl. IV, A) in exactly the same manner as wheat plants are by *tritici*. In fact, but for the slightly different appearance of barley straw from wheat straw, the galls could not be separated once they became mixed. When barley plants are badly infested galls may be found above every joint.

HOST PLANTS.

The writer has now been breeding *hordei* in confinement for 4 years and has never succeeded in inducing it to breed in any plant other than barley.

LIFE HISTORY.

This is one of the easiest species to handle in breeding cages. In fact, it breeds more freely than any other species, *tritici* not excepted.

There is only one generation a year, the larvæ remaining in the old barley stubble until the following spring, when they pupate and then emerge as adults during May, at least in the vicinity of Charlottesville, Va. Plate IV, D, E, and F, shows three positions of a female during oviposition. Figure 2, *d*, *e*, shows the egg before and after oviposition.

H. hordei is normally thelyotokous. In a period of 4 years' breeding, during which several thousand specimens have been reared, not more than three or four males have appeared.

Under actual test one female *hordei* deposited 71 eggs in 3 days and then died. Upon dissection 3 eggs were found in her abdomen. From this it would seem that under favorable conditions for egg laying the lives of adult females of the species are very short. If the weather is stormy and cool, however, they will live two or three times as long.

THE RYE JOINTWORM.[1]

The rye jointworm was described in 1861 (4), so it will be seen that it is one of our earliest known species. For years, however, it was considered an invalid species and was thought to be *hordei* masking under a new name. There appears to be no record of the rye jointworm ever doing as serious injury as *tritici*, *hordei*, or *grandis*.

Harmolita secalis, like *hordei*, is almost extinct to-day and apparently for the same reasons. In fact, it never has had the opportunity to become a serious pest on account of the fact that rye probably has never been grown as generally in adjacent fields and through consecutive years as have barley and wheat. The rye jointworm has had to depend largely upon volunteer rye and to make long journeys to the nearest rye fields in order to maintain itself.

The rye jointworm, in common with several other members of the genus, is thelyotokous, males very rarely occurring and apparently being unnecessary to the vital economy of the species. But for the fact that practically every specimen that emerges is a female and capable of perpetuating its kind, *secalis* would undoubtedly have become extinct long ago.

Fitch described *secalis* from Pennsylvania in 1861. F. M. Webster collected the species in Ohio in 1904 and C. N. Ainslie collected it in Michigan in 1906. The writer has collected it in Ohio, Indiana, and Pennsylvania.

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[1] *Harmolita secalis* Fitch.

MANNER OF INJURY.

Rye plants are affected very much in the same way as are wheat by the wheat jointworm and barley by the barley jointworm. The individual cells or galls in rye (Pl. V, A) usually are more clearly defined or outlined than are those of *H. hordei.* Presumably a serious infestation would cause rye to lodge or fall as badly as barley or wheat, since rye is taller and therefore more top-heavy. The writer has never found a serious infestation of *secalis*, apparently because, as previously mentioned, no locality has been found where rye is grown consecutively on contiguous areas, in consequence of which *secalis* is obliged to resort to volunteer plants that spring up in waste places to maintain its existence at all.

HOST PLANTS.

After 3 years of repeated trials this species has refused to breed on any plant other than rye. Like *vaginicola* it prefers young tender plants for oviposition, absolutely refusing to oviposit in large plants or those that have headed.

LIFE HISTORY.

The writer has had this species under observation since 1912, when the first attempts were made to rear it in confinement. It was reared continuously from that time up until 1916. During 4 consecutive years of breeding only 2 or 3 males appeared among hundreds of specimens all of which were the progeny of 6 female and 4 male individuals with which the series was started in 1912.

The larvæ remain in the old stubble throughout the summer, fall, and winter, pupate in the spring, and emerge as adults about the middle of May. The egg is shown in figure 8 at *b*.

The species *secalis* has been confused principally with *hordei* and undoubtedly also with *tritici* and *websteri.*

THE RYE STRAW-WORM.[1]

The rye straw-worm is another early recorded species, having been first described in 1862 by Fitch (5) under the name *Eurytoma hordei.* There is no record that it ever caused serious injury to rye, and under the conditions that prevail to-day of scattered cultivation of this crop there seems little prospect that it will become a serious pest. In fact, like several other species, it seems to be having a very hard fight to maintain its existence. F. M. Webster collected *websteri* in Illinois in 1884, and D. W. Coquillett took it in California

[1] *Harmolita websteri* Howard.

in 1885. Webster observed this species in rye stalks in Indiana, Ohio, and Virginia in 1904. Since that time the writer has collected it in Ohio, Indiana, and Pennsylvania.

MANNER OF INJURY.

The larva works in the center of the stem just at the joint, in the same way as does the summer form of the straw-worm. The writer has never seen a heavy infestation by this species.

HOST PLANTS.

The writer has bred this species for 8 years in confinement and made various attempts to induce it to breed on other hosts, but without success; it confines itself exclusively to rye.

LIFE HISTORY.

Starting originally with 2 females and 1 male, the writer has reared this species in confinement since 1911. All successive generations are the progeny of these individuals, and among several hundred specimens reared only 1 or 2 males have appeared.

There is only one generation a year and the larvæ remain in the old stubble until spring when they change to pupæ, the adults emerging about the middle of May. The egg is shown in figure 7 at *b*.

SPECIES INFESTING THE CULTIVATED GRASSES.

THE TIMOTHY STRAW-WORM.[1]

The timothy straw-worm has been known since 1894, when it was described by Ashmead (1). Nothing seems to have been learned about its life history until recent years. It is very widely distributed and undoubtedly may be found wherever timothy has escaped from cultivation and grows wild. It is not dependent, therefore, upon artificial plantings of timothy.

MANNER OF INJURY.

H. albomaculata occupies the center of the stem, rasping the inner walls and feeding upon the juices of the plant (Pl. IV, C). Usually it is found just at or slightly above the second joint from the root though it may occur at any joint or at every joint. The injury is apparently not sufficient to decrease the hay crop materially, although a heavy infestation certainly would have a considerable effect in lessening the seed crop.

[1] *Harmolita albomaculata* Ashmead.

HOST PLANTS.

This species has been bred in confinement since 1909 and numerous attempts have been made to rear it on hosts other than timothy, with negative results.

LIFE HISTORY.

Larvæ remain in old stubble and in volunteer growth in waste places throughout the summer and winter, pupating in spring. The adults emerge in May. Males normally occur. The egg is shown in figure 7 at *c*.

THE ORCHARD GRASS STRAW-WORM.[1]

The orchard grass straw-worm was recently described by the writer and Mr. W. T. Emery (10, p. 446). It was found first in 1904 by F. M. Webster, according to Bureau records. Since that time it has been collected by various members of the branch of Cereal and Forage Insect Investigations. The writer has been rearing it in confinement since 1914. It has been reared from orchard grass collected in Massachusetts, New York, Pennsylvania, Ohio, Michigan, Maryland, Virginia, Tennessee, and Utah.

MANNER OF INJURY.

H. dactylicola affects the plant in the same manner as does *albomaculata*. The writer has never found orchard grass as seriously affected as timothy, one reason probably being that it is not grown as generally. Orchard grass probably will not be as seriously injured by *dactylicola* as timothy is by *albomaculata* since the former plant is larger and more woody than timothy.

HOST PLANTS.

This species has not been reared from any host other than orchard grass.

LIFE HISTORY.

Larvæ remain in the old stubble and in old volunteer plants throughout the summer and winter, pupate in the spring, and emerge as adults in May. Males normally occur.

THE BLUE-GRASS JOINTWORM.[2]

Howard (8, p. 13) first described the blue-grass jointworm in 1896 from specimens captured by F. M. Webster in a rye field in 1885 at Normal, Ill. Webster later swept it from timothy and blue-grass at La Fayette, Ind. (14; 8, p. 13). Lintner (9) states that he reared a number of specimens of this jointworm from galls in wheat

[1] *Harmolita dactylicola* Phillips & Emery.
[2] *Harmolita captiva* Howard.

stems in New York in 1888. It is supposed that *captiva* was the species involved in the latter case, but doubt is cast upon this supposition by Lintner's statement that part of the specimens were typical *hordei* (*tritici*), and part were much larger, the latter being *captiva*. The species the writer knows as *captiva* is much smaller than *tritici*; besides, *captiva* has been reared from galls in blue-grass, and should it breed in wheat also it will be the second species known to infest plants belonging to separate and distinct genera. This is not at all impossible but at present it seems improbable. As the New York case is the only one recorded where the species has been reared from wheat it seems reasonable to suppose that another species than *captiva* was involved.

The writer reared specimens of *captiva* from galls in blue-grass collected near Richmond, Ind., in 1905. It has not been reared since. Nothing is known of its life history except that it undoubtedly has only one generation a year and that both males and females were reared. The galls (Pl. III, D) occur near the base of the seed stalk where the stem is thick. As the seed stalks of blue-grass are slender and rather frail the stem at the point where the galls occur does not seem to be very woody. The cells are arranged in a row end to end, there being insufficient room, apparently, for the larvæ to have cells side by side in the stalk as in some other species.

THE BLUE-GRASS STRAW-WORM.[1]

The blue-grass straw-worm was described only recently by the writer and W. T. Emery (10, p. 445) but undoubtedly has been breeding in blue-grass (*Poa pratensis*) for years. Very probably it has been confused with *H. captiva* and perhaps with other species. The first records of *poae* are by F. M. Webster and the writer in 1905. It is a widely distributed species and doubtless can be found wherever blue-grass grows normally.

MANNER OF INJURY.

The writer has never had the opportunity to visit sections that grow blue-grass seed to learn to what extent infestation exists. The only infestation found has been where the grass grows wild in protected places, such as along fences. Pastures usually are kept cropped close by stock and there is little chance for *poae* to breed. It works in the center of the stem and undoubtedly would injure the seed crop greatly, as the seed stalks of blue-grass are slender, soft, and rather fragile, not at all hard and woody like the majority of the grasses affected by other species. The cavity in the stem is scarcely

[1] *Harmolita poae* Phillips and Emery.

large enough for the larva, and as the walls of the stem are very thin it is easy to see that the larva would consume a large part of the nourishment required for the developing seed and cause serious loss in case of a heavy infestation.

HOST PLANTS.

H. poae has not been reared from any host other than blue-grass (*Poa pratensis*) although a number of attempts have been made to breed it in other hosts.

LIFE HISTORY.

As previously indicated, this species hibernates in the seed stalks of blue-grass in waste places and along fences since pastures are kept cropped so closely that there is little chance for it to winter over there. It hibernates as a larva, pupates in spring, and the adult emerges early in May. It is one of the first species to make its appearance in the spring. Males normally occur. The egg is shown in figure 8 at *e*.

THE FESTUCA JOINTWORM.[1]

The Festuca jointworm was described recently by the writer and W. T. Emery (10, p. 454) from specimens reared from material collected by the writer near Youngstown, Ohio, in 1913. Since that date it has been located at other points in Ohio, New Jersey, Pennsylvania, and Virginia. It is the slenderest species among the gall formers, the abdomen being particularly long and narrow.

MANNER OF INJURY.

H. festucae forms galls or hardened enlargements, usually above the second joint from the ground, although they may occur at any joint. The galls (Pl. VI, C) may be prominent or inconspicuous; in the latter case they can be detected only by pinching the stems between the fingers. The injury undoubtedly would be serious to the seed crop and very probably would shorten the hay crop, also, as the flowering stalks are rather slender, and although not quite as frail, they are very much like blue-grass stems in that they are not woody. *Festuca* sp., therefore, would naturally suffer more from attacks of this kind than would orchard grass or timothy.

HOST PLANTS.

The writer has been rearing *festucae* from *Festuca* sp. in confinement and making observations in the field for 5 years and has not reared this species from any other host.

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[1] *Harmolita festucae* Phillips and Emery.

LIFE HISTORY.

As this grass grows naturally in waste places and along fences its jointworm enemy does not depend upon cultivated areas to maintain itself. It winters in the old seed stalks as pupa, the adult emerging near the middle of May. The species is normally thelyotokous, males very rarely occurring.

SPECIES INFESTING WILD GRASSES.

In the preceding pages the writer has given briefly some of the more important facts relating to all the species at present known to infest our grains and cultivated grasses. It may appear at first glance that wheat has rather more than its share of species, especially since it is our most important small grain. On the other hand, the genus Elymus, a wild grass, is the home of nine species, eight of which are gall-formers; *Agropyron* sp., another wild grass, has four species, three of which are gall-formers. The species infesting the wild grasses will be dealt with very briefly. A good many of them may lay a just claim to some consideration from an economic standpoint, from the fact, as previously stated, that they have parasites in common with the more important economic species.

HARMOLITA MACULATA Howard.

Howard (8, p. 15) described this species as *Isosoma maculatum* in 1896 but nothing was known then of its life history. In recent years it has been collected by various members of the branch of Cereal and Forage Insect Investigations. The writer has reared it in confinement since 1912. It has persistently refused to breed in any host other than grasses of the genus Bromus. It does not form galls but lives in the walls of the plant stem, particularly of cheat (*Bromus secalinus*). The cheat stem is almost solid near the base, at least just above the lower joints, the walls being very thick. The egg (fig. 8, *d*) apparently is deposited in the walls of the stem somewhat like the egg of *tritici* and the larva excavates a little tunnel about half an inch long just above the joint (Pl. V, B). There are sometimes two or three to an internode. It is a very widespread species and undoubtedly occurs wherever cheat or other species of Bromus are found.

There is only one generation a year. The species hibernates in the larval stage, pupates in the spring, and the adults emerge in May. It is arrhenotokous under control conditions though in nature both sexes occur.

HARMOLITA ATLANTICA Phillips and Emery.

Harmolita atlantica (10, p. 461) is a species which the writer first reared near Richmond, Ind., in 1909. A few specimens have been

taken in Michigan and many in New York. It has been reared sparingly in confinement, not being a very tractable species. It has never been reared from any host other than Agropyron.

This species forms galls in the stems. Some of the galls resemble somewhat those of *tritici*, being placed in the walls of the stem; others resemble those made by *vaginicola*, occurring in the sheath surrounding the head. In the latter case the head does not appear at all. (Pl. VI, B.)

There is only one generation a year, and, as with the majority of species, they pass the winter as larvæ in the galls of the old plant stems, pupate in the spring, and emerge as adults in May. The species is normally thelyotokous, males rarely occurring.

HARMOLITA AGROPYROPHILA Phillips and Emery.

Harmolita agropyrophila (10, p. 450) is the only species, besides *grandis*, that has two generations a year. Singularly enough, Agropyron is one of the few plants infested by Harmolita that produce stems continuously throughout the growing season. The majority of the other jointworm species would find it difficult to maintain two generations a year on a single host unless they were dimorphic like *grandis* and one generation developed in the very young plants.

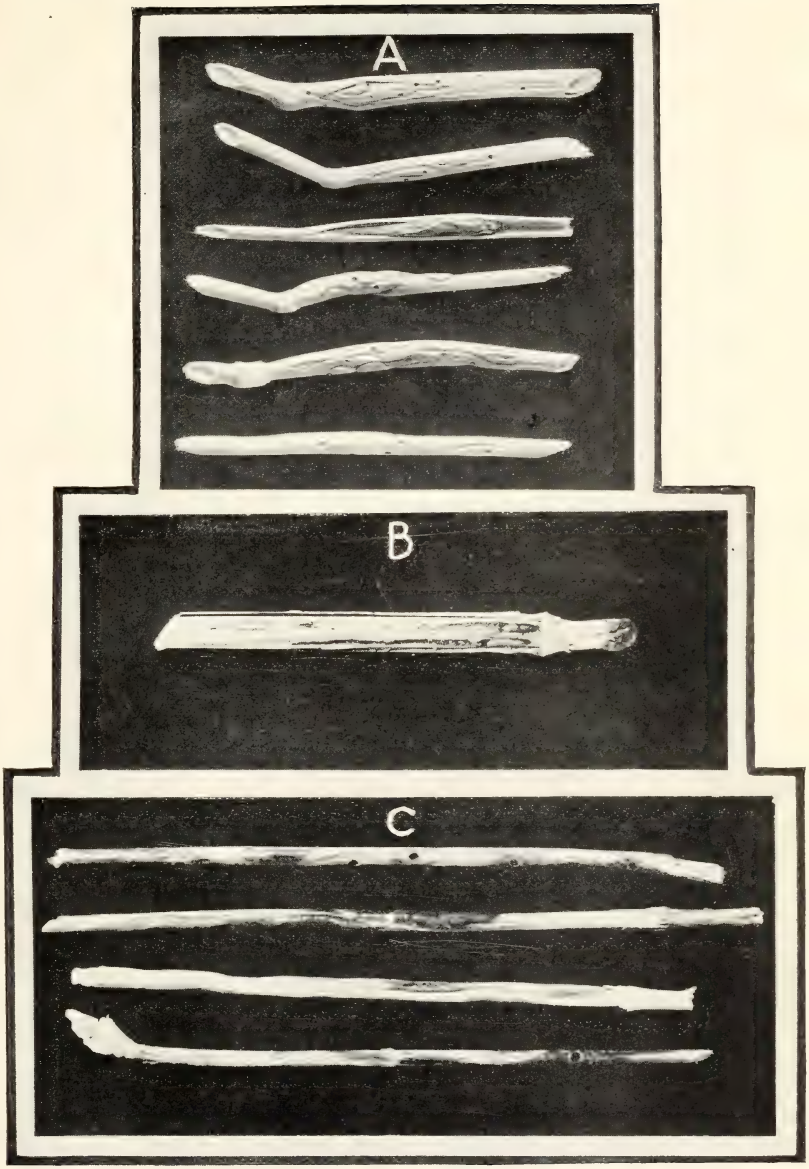
H. agropyrophila was collected first in 1904 by F. M. Webster. Since that time it has been collected by various members of the branch of Cereal and Forage Insect Investigations. The writer has been rearing and observing this species since 1905, when he first discovered that it has two generations in a year. The larvæ inhabit the center of the stem and may be found at any joint.

The species has never been reared from any host other than Agropyron although repeated attempts have been made to induce it to live on other plants in confinement. There are two generations a year, the first generation emerging very early, during the last week in April and the first week in May. It is one of the first species to emerge. The second generation emerges the latter part of June and the first week in July.[1] The second generation deposits its eggs (fig. 2, *g*) in the young tender stems, and as it is rather late in the season these stems do not produce heads.

HARMOLITA ELYMI French.

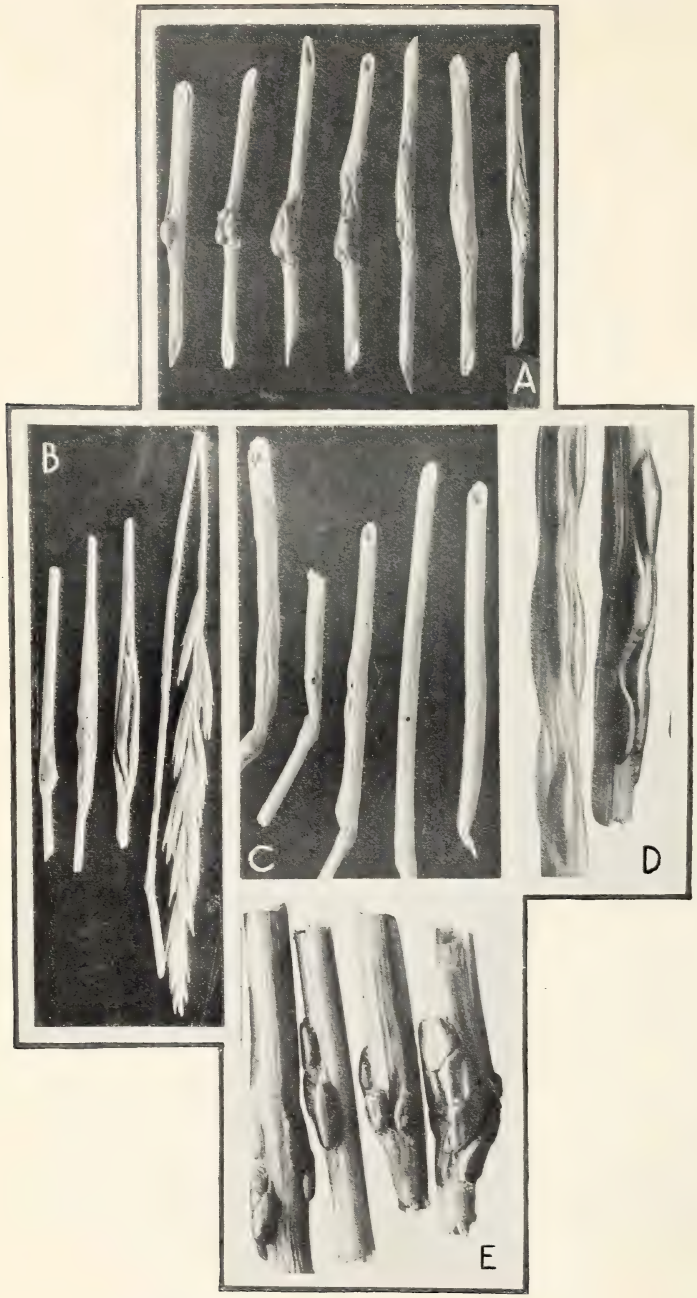
This species was described as *Isosoma elymi* in 1882 by G. H. French (6), who reared it from *Elymus americanus* from Carbondale, Ill. The writer's attention was first attracted to it in 1908, when it was learned that it occupied the center of the stem of *Elymus* sp.

[1] These dates apply to Richmond, Ind.



JOINTWORM FLIES OF THE GENUS HARMOLITA.

A, Characteristic gall of the rye jointworm (*H. secalis*) in rye (about natural size); B, larvæ of *H. maculata* in a cheat stem (about natural size); C, galls of *H. elymivora* in *Elymus* sp. (about natural size).



JOINTWORM FLIES OF THE GENUS HARMOLITA.

A, Characteristic galls of *H. elymicola* in *Elymus* sp., slightly reduced; B, two types of injury to *Agropyron* sp. by *H. atlantica*, those to the left being sheath galls and the long stems to the right being stem galls, slightly reduced; C, Typical galls of the Festuca jointworm (*H. festucae*), about natural size; D, E, characteristic galls of *H. elymophthora*, enlarged slightly. (Photographs D and E by Mr. C. N. Ainslie.)

Nothing was known of its life history until recent years. It has a wide range, being found as far west as Utah, and having been reared from collections of Elymus from Illinois, Indiana, Ohio, and Virginia. It probably occurs wherever *Elymus* sp. grows normally.

H. elymi inhabits the center of the stem of *Elymus* sp. and has never been reared from any other plant, although repeated attempts have been made to rear it from wheat, rye, barley, and some of the grasses. There is only one generation a year. Hibernation is in the larval stage, pupation occurs in the spring, and the adults emerge in May. This species is thelyotokous, males never having been observed.

HARMOLITA ELYMICOLA Phillips and Emery.

Harmolita elymicola (10, p. 460) is the commonest species on Elymus in the Eastern States and is apparently a strictly eastern species, as it has not been collected west of the Mississippi River with the exception of southeastern Missouri. East of the Mississippi it has been taken in Illinois, Indiana, Michigan, Ohio, and Virginia.

It forms very prominent galls or enlargements, usually above the second joint from the base of the plant (Pl. VI, A). It has never been reared from any host other than Elymus. Repeated attempts have been made to breed the species on wheat, barley, and various grasses. It has been observed to oviposit in wheat and barley stems, but nothing ever developed in these stems. Figure 8 *c*, shows eggs of this species.

H. elymicola has only one generation a year. It hibernates as a larva in the old seed stalks, pupates in the spring, and emerges in May. It has proven to be arrhenotokous under control conditions, but both sexes normally occur in nature.

HARMOLITA ELYMIVORA Phillips and Emery.

Harmolita elymivora (10, p. 464) is not nearly as abundant as *elymicola*, though it apparently has a wider range, having been found as far west as Arkansas. It has also been reared from stems of *Elymus* sp. collected in Indiana, Michigan, Ohio, and Virginia.

H. elymivora forms galls in the stems of *Elymus* sp. just below the head. As a result, the head or fruiting body of the plant never develops (Pl. V, C). It is possible that it forms galls of the *elymicola* type also, but the writer has never reared any from such galls.

The life history is similar to that of *elymicola*. Eggs are shown in figure 2, *c*.

HARMOLITA RUFIPES Phillips and Emery.

Harmolita rufipes has been described only recently (10, p. 453), but F. M. Webster is probably the first to have reared it. In Bulletin 42 of the Division of Entomology Prof. Webster confused this species

with *H. hordei* Harris, stating that he had reared *hordei* from Elymus at Champaign, Ill. The writer has examined these specimens and they are very clearly *rufipes*. The species resembles *hordei* somewhat in that the legs are reddish brown, but it is much larger than *hordei* and other characters very readily distinguish them. *Rufipes* is apparently a strictly western species, never having been reared any farther east than Champaign, Ill. It has been reared from *Elymus* sp. collected in Kansas, Nebraska, New Mexico, and Utah. It has never been reared from any grass other than *Elymus* sp. Repeated attempts were made by the writer to rear it in confinement at both La Fayette, Ind., and Charlottesville, Va., upon its host, but it has steadily and persistently refused to breed. It apparently would oviposit, but no larvæ ever developed. It forms galls in the stems of *Elymus* sp. Nothing is known of its life history further than that it has a single generation during the year, hibernating in the usual way and emerging in May. Both sexes occur.

HARMOLITA HESPERUS Phillips and Emery.

Harmolita hesperus (10, p. 457) was considered by the writer for quite a while to be *rufipes*. The two species can be distinguished, however, very readily. *H. hesperus* is apparently a strictly western species, having been reared from *Elymus* sp. collected from Kansas and Utah, but it has never been found east of the Mississippi River.

H. hesperus forms galls very much as does *elymicola*. It has not been reared from any plants other than *Hordeum jubatum* and *Elymus* sp. Nothing is known of its life history further than that it hibernates in the usual way and emerges in May. Both sexes occur normally. The writer has never been able to rear this species in confinement, though repeated attempts have been made to rear it in *Elymus* sp., both at La Fayette, Ind., and at Charlottesville, Va. The egg is shown in figure 7 at *a*.

HARMOLITA ELYMOPHTHORA Phillips and Emery.

Harmolita elymophthora (10, p. 465) appears to be a strictly western species also, having been reared only from Nebraska and North Dakota. It was first brought to the writer's attention by C. N. Ainslie, who sent in galls on *Elymus* sp. from which was reared this species. It forms galls in *Elymus* sp. (Pl. VI, D, E), though it is not known whether it has other hosts or not. It has refused to breed in confinement at Charlottesville, Va. It has one generation a year and both males and females normally occur.

HARMOLITA OVATA Phillips and Emery.

Harmolita ovata (10, p. 458) has been reared only from Kansas. It was sent to the writer in the fall of 1914 by E. O. G. Kelly, who was

then a member of the Cereal and Forage Insect Investigations force. It forms galls in *Elymus* sp. It is not known whether it has other hosts. It refused to breed in confinement at Charlottesville, Va. There is one generation a year and apparently both males and females occur.

SPECIES WHOSE BIOLOGY IS UNKNOWN.

The species previously treated in this paper have all been reared repeatedly in cages under artificial conditions with the exception of *captiva*, *rufipes*, *hesperus*, *elymophthora*, and *ovata*. The writer has never seen living specimens of the remaining six species described by Phillips and Emery (10)—*poophila*, *agropyrocola*, *occidentalis*, *elymophila*, *elymoxena*, and *gillettei*—or of *bromicola* Howard and *agrostidis* Howard, and practically all that is known concerning them is contained in the meager data incidental to collection. Four of these, *agrostidis*, *bromicola*, *elymoxena*, and *elymophila*, are from California; two, *gillettei* and *poophila*, are from Colorado; one, *agropyrocola*, from Utah; and *occidentalis* from New Mexico. Nothing, of course, is known of their life histories. *Poophila* was reared from *Poa lucida*, sent in by A. D. Hopkins from Husted, Colo.; *agropyrocola* and *occidentalis* were reared from *Agropyron* sp., the former reared from material sent in by Desla Bennion and the latter from material forwarded by V. L. Wildermuth; *bromicola* was reared from *Bromus ciliatus; agrostidis* was reared from *Agrostis* sp.; *elymophila* and *elymoxena* were reared from *Elymus* sp. The four last species were collected by Albert Koebele. *H. gillettei*, as the name implies, was reared by C. P. Gillette and was named for him; the host is unknown. Undoubtedly further observations and collections will add many more new species from the Western States, and more particularly from the Pacific Coast States.

CONTROL MEASURES.

Farmers, as well as entomologists, have concerned themselves very little about controlling these really serious pests. Fortunately or unfortunately, depending upon the point of view, the parasites have taken care of the situation to such an extent that only now and then the jointworm (*H. tritici*) gets out of hand and causes the almost total destruction of a crop in a given locality. Therefore the matter has been viewed very calmly and a toll of from 1 to 5 bushels or more per acre has commonly been tolerated. We have been perfectly content to pay an annual tribute in preference to fighting vigorously to throw off this burden. But for the parasites we should have been obliged to bestir ourselves long ago or else abandon wheat growing in the Eastern States. There is some excuse for this condition of

affairs, in that there was no very simple remedy at hand; for example, simply spraying the wheat would not cure the trouble.

The writer has studied the situation for years and has found that most if not all of the so-called remedies are useless. For several winters futile attempts were made to burn over stubble fields in Indiana. In the first place the ground must be frozen or the burning will destroy the young clover and at no time during the winter could the stubble be burned under these conditions. This would be the simplest of all remedies if it were practicable, although it would destroy a source of humus. Another supposed remedy was to plant wheat as far from the old stubble as possible. This is folly unless the farm in question covers an area of several square miles. The jointworm can fly and may be carried by the wind at least for a mile. The suggestion of sowing wheat early, in years of scarcity of the Hessian fly, is equally futile. V. L. Wildermuth, of this bureau, made observations on 51 fields at Groveport, Ohio, in 1909, in order to determine the effect of early and late sowings in relation to jointworm injury. Twenty-eight fields sown from September 10 to 30, with an average date of September 24, showed an average infestation of 38 per cent, with an average yield of 8½ bushels per acre; 15 of these fields produced grain of good, 10 of medium, and 3 of poor quality. On the other hand, 23 fields sown October 1 to 24, with average date of October 10, showed an average infestation of 19 per cent with an average yield of 20 bushels per acre; 11 of these produced grain of good, 9 of medium, and 3 of poor quality. These observations show also that whether the wheat were sown early or late the wheat on poor ground always was infested to a greater degree, provided the fields were equally distant from the source of infestation. The writer's observations confirm this idea.

Some writers have suggested that the larvæ would be destroyed if the infested stubble should pass through stables and then be subjected to the process of decomposition incidental to composted manure. The writer therefore placed infested stubbles in horse stables and allowed them to become mixed with the droppings in the ordinary way. They were then removed to the center of a heap of manure and part of them allowed to remain in the manure all winter while the remainder were removed after having remained in it for two weeks, and then scattered on the ground and allowed to remain there undisturbed throughout the winter and spring. Those remaining in the manure pile were removed the last week in March, and placed in confinement for observation, as were those that were scattered on the ground in early winter. Each lot produced about the same number of adults as did stubble that was allowed to winter in the usual manner in the field. This experiment certainly indi-

cates that there is small hope of destroying the jointworm by passing infested straw through the manure pile.

The writer has been experimenting for the past three years in plowing under wheat stubble for the purpose of observing the effect on infestation the following year in wheat planted on the same ground. This work was done in the vicinity of Charlottesville, Va., where no infestation occurred nearer than 5 or 6 miles. Therefore the data secured should be reliable, as there was no opportunity for the jointworm to come in from neighboring fields. Small plats were used and the infestation was accomplished by bringing in a very large amount of infested stubble from a distance, placing it in the growing wheat, and allowing the adults to emerge and infest the plat. In order to insure heavy infestation, large amounts of badly infested stubble were brought in again from a distance after the wheat was cut, making accurate counts of the number thus brought in, and then carefully estimating the infestation that already existed on the plat. The total number of wheat stems or stubbles was then counted on several representative square yards of the plat. In this way the percentage of artifical infestation could be determined accurately. The infested stubbles which had been introduced, together with the stubbles already standing on the plat, were then turned under. The ground was plowed as soon after harvest as possible, disked, and some crop like peas or soy beans sown. The plat was disked again in the fall at the proper time and reseeded to wheat. In this way an 8 per cent infestation was reduced to 1 per cent the following year. A second trial reduced the infestation from 32 per cent to 3 per cent. A third trial in 1918 reduced a 19 per cent infestation to 2 per cent.

These experiments indicate that plowing under stubble is a very effective remedy. It doubtless would destroy all of the insects if all of the infested stubbles could be completely buried, but it is impossible to do this. Nevertheless it is practicable to control the ravages of the species in this manner. While this method of control would necessitate a change in the existing rotation of crops where wheat is used as a nurse crop for clover, it would seem that it should be adopted if millions of dollars could be saved every year in this manner. Some agronomists admit that it would be practicable to change the existing system of rotation so as to permit plowing down stubble to suppress important insect pests. If this were done not only the jointworm but also the Hessian fly would be controlled, and thus two of the major insect pests of wheat would be largely shorn of their power for harm to our most valuable bread grain.

The barley jointworm, the rye jointworm, and the rye straw-worm undoubtedly can be controlled in the same manner, if the necessity arises.

The wheat straw-worm is very easy to control. Since one generation is wingless it is only necessary to keep down all volunteer wheat and never plant wheat nearer than 40 to 50 yards to infested stubble. This is allowing a wide margin of safety since they are supposed to be able to travel at most only 12 or 15 feet.

Should it become necessary to control the straw-worms and jointworms infesting our cultivated grasses, such as timothy, orchard grass, blue-grass, and *Festuca* sp., this undoubtedly could be accomplished by clipping such fields in the spring in order to delay the appearence of seed stalks until the emergence of the insects, when there would be no place for them to deposit their eggs.

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